B U T T E R   O I L

A Review of Literature

I. Food Product of the United States

II. Ghee.--Food Product of the Middle East

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BUTTER OIL

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I. Food Product of the United States

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Butter oil, dry butterfat, dry milk fat, or dehydrated milk fat is not a new product. Such a product was made years ago in India and Egypt, but only in recent years has it been made on a commercial scale in the United States. United States standards for the product have not been promulgated. During World War II, the United States Department of Agriculture, however, issued a processing procedure for preparing butter oil from butter and tentative specifications requiring that the finished product be a bland oil containing not less than 99.4 percent of butterfat, not more than 0.5 percent moisture, not more than 0.1 percent salt and milk constituents not-fat, and showing no signs of cloudiness prior to cooling and packaging.

In June 1950, Military Specifications (MIL-M-3233) were issued for Anhydrous Milk Fat--a product prepared by the removal of water and serum solids from milk and/or cream by physical means. According to these specifications, the finished product should be of a uniform normal yellow butter color, free from lumps and large crystals. Its flavor and odor should be sweet and clean and free from rancid, tallowy, fishy, cheesy, soapy, storage, or other objectionable flavors and odors. It should contain not less than 99.8 percent milk fat, not more than 0.1 percent moisture, not more than 0.5 percent of free fatty acids, and not more than 0.25 p.p.m. of copper. Its peroxide value should be zero.

The commercial value of butter oil and its best place in the market for maximum use are debatable. The present butter situation has resulted in a renewed interest in butter oil as a possible outlet for surplus butter. It therefore is advisable to review, at this time, the research work on the manufacture, use, storage life, and other related aspects of butter oil.

REVIEW OF EXPERIMENTAL WORK

Experiments, in 1916, by Mendel (29)[1/] et al. indicated the pronounced stability, under ordinary conditions of storage, of a growth-promoting substance in butterfat. They found the growth-promoting factor to be more concentrated in butter oil than in butter but noted a gradual deterioration so that in a year the potency of the factor was almost completely lost.

1/ Underscored numbers in parentheses refer to Literature Cited, pp. 10-12.

Dyer (13), in 1916, reported that the development of undesirable flavors in butter held in cold storage at a temperature of 0° F. was not dependent upon an oxidation of the fat itself, but might be due to a slow oxidation progressing in one or more of the nonfatty substances occurring in the buttermilk. The extent of the chemical change was found to be directly proportional to the quantity of acid present in the cream from which the butter was prepared. He stated that it would appear that any oxidation of pure butterfat kept in storage at 0° F. for a reasonable length of time must be extremely small.

Hunziker et al. (24) reported, in 1917, on samples of butter oil made by heating creamery butter to 55° to 60° C., sealed in airtight containers, held at room temperature, and examined each month for an 11-month period. No appreciable change was noted in the butter oil the first 2 months. Rancidity began to develop at the end of the third and fourth months. At the end of the fifth month, the rancid flavor had become very intense. The fat contents underwent only very slight change, and it was concluded that slight changes in butterfat contents may, and do, produce very marked deterioration in the flavor of the butterfat. It, however, was also determined that in storage butter, protein hydrolyses played a prominent role in deterioration.

In 1922, Baker (7) and North (32) were issued patents on processes to manufacture butter oil from cream. During the next few years North and his associates were issued many more patents concerned with the manufacture of butter oil. In 1926, North and Larner (33, 34, 35) were issued patents for processes of manufacture of butter oil from milk, cream, and sour cream. To produce butter oil from milk, the milk was separated, the cream washed, and the washed cream diluted with water and the diluted cream maintained at the proper temperature for a sufficient time to break the emulsion and coagulate the casein. The hot layer of oil was then filtered and dried. To produce butter oil from cream, another method was patented as follows: Whip cooled cream, heat the whipped cream until the fat melts and the curds coagulate; mix with water, and allow the mixture to settle and the oil to rise to the surface. To produce butter oil from sour cream according to the patent, the procedure is: Evaporate the cream until all the water is removed and complete coalescense of the fat globules result, filter the resulting oil to remove any suspended curds.

Greenbank and Holm (18), in 1924, in reporting on factors concerned in the autoxidation of butterfat stated that it was apparent from data presented that no factors controlled the keeping quality to a greater extent than did the acidity of the fat and the temperature at which it is stored. They further stated that in view of the fact that a fresh butterfat of low acid content would strongly resist oxidation, even at room temperatures, with free access to air, there could be no doubt that acidity was one of the crucial factors to be considered in preparing fat of good keeping quality. Steam distillation (not to be continued too long) or thorough washing of butterfat was reported to increase materially its ability to withstand oxidation changes. The keeping quality of butterfat was reported also to be increased by processing to remove the fatty acids.

Holm et al. (22) reported, in 1927, evidence of the existence of loosely bound oxygen compounds in butter oil. They concluded that as a result of these substances termed "moloxides," inert gases or vacuum were not absolute safeguards against oxidation of some fats.

Newlander and Ellenberger (30) reported, in 1929, that although some butter oil kept in good condition for short periods at temperatures as high as 50° F., storage temperatures above 0° F. were not recommended. They also stated that in order to obtain a high-quality product after storage for 4 to 6 months at 0° F., whether the stored product be cream, butter, or butterfat, the original product must be of exceptionally high quality. They found that when average quality cream was used, the keeping quality of butter oil surpassed that of cream or butter by a wide margin.

Greenbank and Holm (19) reported, in 1930, that the rate of reduction of methylene blue in a fat or oil when catalyzed by light might serve as a measure of the rate of reaction of the initial oxidative processes and might, therefore, be utilized to determine the relative susceptibility of fats and oils to oxidation.

In 1933, Washburn (44, 45) stated that much of the undesirable flavor of butter was contained in the watery constituent rather than in the fat. He suggested that butter oil be separated from butter by a gravity or centrifugal method and the fat be used as such in ice cream mix. He stated that the butter oil would have a better flavor than the butter from which it was made.

Greenbank and Holm (20) reported, in 1934, that of the phenols, only the ortho and para types are active as antioxidants for fats and oils. Hydroquinone and catechol were antioxidants, but resorcinol was not. Maleic acid (an unsaturated polybasic aliphatic acid) was also found to be an antioxidant for fats and oils.

Greenbank (17), in 1936, studied the rate of oxidation of fats in storage. He reported the rate of oxidation to be influenced by: (a) The kind and amount of unsaturated fatty acid constituents of the glycerides; (b) those constituents that act as antioxidants and prooxidants; (c) the conditions to which fats are subjected. The prooxidants in butter oil were found to be very volatile. Storage of the oil in vacuum or inert gases was reported as retarding but not preventing oxidation. Heat increased the rate of oxidation. In the presence of air at low temperatures, light was found to be the most powerful acceleration of oxidation, followed by moisture and heat.

Lea and Hale (26), in 1939, stated that washing cream by dilution to the volume, or even to half the volume, of the original milk, followed by separation, gave a cream from which butterfat could readily be obtained by evaporation of the water in vacuo, and subsequent filtration. Evaporation of the water from the cream was carried out at a relatively low temperature in order to avoid production of a "butter-taffee" flavor.

Butterfat so prepared or that produced by the boiling process at atmospheric pressure was found to resist oxidation at 100° C. for a considerable period, thus indicating a probable storage life of some months at ordinary temperature.

In 1941, Loftus-Hills (27) described an experimental plant for the preparation of butterfat from butter. The equipment consisted of a melting vat, 2 neutralizing vats, 2 separators, evaporator-condenser, cooler, and a balance tank for filling containers. It was reported that the rate of separation was markedly increased by adjusting with soda the pH of the butter serum after melting to pH 10.

Riddet (38), in 1942, reported on a 10-ton trial order for butter oil. The butter oil was made from unsalted butter of low moisture. The butter was melted with steam, part of the serum was allowed to separate out by gravity, the top portion was then passed through 2 separators, a dehydrator (adapted Vacreator), tubular cooler, and then packaged in 4-gallon tin containers. After the trial order, whey butter was used and was found to be easier to process. The butter oil produced showed good keeping properties at ordinary temperature, was remarkably free from traces of caramel flavor, and could be used in place of butter for a variety of products including ice cream and reconstituted butter although the latter product was reported as having a somewhat metallic taste. Additional reports (2, 3, 4, 8) on this process were made in 1942.

In 1942, Noble (31) reported that investigation and analysis of dehydrated butterfat had shown that the product was permanently stable, largely immune from bacterial attack, and almost wholly immune from oxidation taint under conditions of open storage. He stated that the following features of dehydrated butterfat had been established by research: (a) Food value similar to original butter; (b) refrigeration unnecessary in storage and shipment; (c) can be reconstituted into butter by adding emulsifiers and water; (d) may be free from the degrading taint if made from second-grade butter; and (e) is interchangeable with butter for addition to margarines, ice cream, and bake-house products.

In 1942, the work of Holm and Trimble, Bureau of Dairy Industry, United States Department of Agriculture, was reported (1). Butter oil was made by melting butter. The melted fat was then floated off the water and serum, centrifuged to remove excess water and curd, and then vacuum-dried with agitation to remove the final traces of water and also the oxygen and other gases that would cause spoilage. The oil was then allowed to flow slowly into the final container under vacuum. The vacuum was then broken, the head space of the container filled with nitrogen, and the container sealed. By this process, a butter oil that would keep almost indefinitely under extreme conditions was made from a butter that had been manufactured from fresh cream. The necessity for the use of high-grade butter was emphasized by pointing out that earlier attempts to produce butter oil commercially had failed because competition among the manufacturers had resulted in the use of low-grade butter as a source of the oil. The inferior quality of the resulting oil had soon ruined the demand for the product. Butter was made from the butter oil produced by the Bureau by stirring powdered skim milk and water into the oil, pouring the emulsion slowly or in small streams into ice-cold water. This resulted in the formation of butter granules that could be worked into butter the usual way.

McDowall et al. (28), in 1942, reported a process for the manufacture of butter oil. The butter was melted by steam under 1-pound of pressure. Part of the serum was separated by gravity and siphoned off. The fat was centrifuged, pasteurized, recentrifuged, and dried in a vacuum pan. The butterfat was found to be free from "taffed" flavor and to have excellent keeping qualities. There was no loss of vitamin A.

Holm et al. (23), in 1943, reported that spoilage of oils and fats might result from enzyme action or from oxidation or both. Enzyme spoilage was reported as generally being prevented by heat, but oxidation spoilage could only be prevented by exclusion of oxygen. It was found that the removal of oxygen in butter oil was relatively difficult but that it could be accomplished with agitation of the fat under vacuum. Butter oils with a dissolved oxygen concentration of less than 0.5 percent by volume and sealed in atmosphere of nitrogen were found to remain in good condition for long periods under severe storage conditions.

Ewbank and Gould (15), in 1943, determined that heating either butter or butter oil to 127° C. for 30 minutes hastened the oxidation of the oil. When cream was flash heated to 70.6° C., heated to 109.8° C. or 127° C. and held 15 minutes, heated to 62.8° C. and held 30 minutes, the two higher processing temperatures shortened the induction period of the resulting butter oil. Butter oil obtained from cream pasteurized at 90.6° C. for 15 and 30 minutes was not adversely affected by the longer heating periods but instead appeared to be stabilized to a slight degree. Cream containing 5 p.p.m. of added copper and pasteurized at 85° C. flash and 90.6° C. flash was found to produce butter oil of stability equal to that of a control sample pasteurized at 62.8° C. for 30 minutes and containing no added copper. Cream pasteurized at 62.8° C. for 30 minutes and containing added copper oxidized extremely rapidly in comparison with the other lots. The stabilizing influence of temperatures of 85°C. and 90.6° C. was found about equal regardless of the time the metal contamination took place (before or after heating). The authors concluded that the heat influence was doubtless due to the formation of hydrogen sulfide and sulfhydryl groups which inactivated the copper sufficiently to prevent full catalytic action.

Gould et al. (16), in 1943, studied the peroxide-carotenoid relationship in fresh butter oil oxidized under controlled conditions, in an oven heated to 100° C. Their results indicated that carotenoid destruction proceeded rapidly during the initial stages of peroxide formation and bleaching. They concluded it would appear feasible to use carotenoid determinations for quantitatively measuring oxidative changes in butter oil and also for detecting the comparative oxidative stability of butter oil from different sources.

Schaffer and Haller (39), in 1943, reported that the solubility of hydrogen, oxygen, air, nitrogen, and carbon dioxide was slightly greater in butter oil than in cottonseed oil and lard at 40° C. The solubility of all gases except hydrogen decreased when the temperature of the oil was increased from 40° to 60° C. It was found that vigorous shaking in a high vacuum at a temperature close to 100° C. was necessary for complete removal of all dissolved gases.

In 1943, Thiel (43) reported that in determining the moisture content of butterfat the entrainment with nitrogen and the Fischer titration method gave similar results but the toluene distillation method gave 0.015 percent lower results. Heating in a hot-air oven at 103° C. for 3 hours, heating on a hot plate for 1-1/2 to 2 minutes followed by 40 minutes in a vacuum oven, and heating on a hot plate of 160° C. for 3 to 4 minutes, all gave consistent results equal to or only slightly lower than those obtained by the titration method.

El-Rafey et al. (14), in 1944, reported that butter oil made by the process in which butter was heated to 110° C. and centrifuged to remove the residue was more resistant to oxidative rancidity than when lower temperatures were used. The improved keeping quality was shown to result from the transfer of greater amounts of phospholipid material from the non-oil phase of butter to the oil. The concentration of reducing substances was also higher in the butter oil made by the "boiling-off" process than by the low-heat treatment. However, the additional stability gained by heating to 130° C. instead of to 110° C. in the "boiling-off" method was not believed to be great enough to offset the disadvantage of a cooked flavor. Butter oil was least stable when prepared by filtration. Washing of the fat was also deterimental to its stability. The method of preparation of the oil had no significant effect on the hydrolysis of the fat and had little or no effect upon the preservation of the vitamin-A activity during processing.

In 1945, it was reported (5) that New Zealand dry butterfat made excellent ice cream, had high keeping quality, and contained from 0.2 to 0.4 percent moisture.

Remaley (37), in 1946, reported observations made when large amounts of butter were converted into butter oil for export under the Lend-Lease program. He stated that satisfactory butter oil could not be made from tallowy, metallic, fishy, or excessively oily butter. The process that produced a satisfactory oil was as follows: Butter, melted at high temperatures; supercentrifuged; oil washed with hot air and dried under vacuum. Oil that was prepared in this manner and hermetically sealed in air kept approximately 90 days without developing oxidized flavor at 100° F. It was reported that high heat (240° F.) following centrifugation caused immediate oxidation to occur. Remaley also stated that deaeration and gas packaging were in the experimental stages, and that standard gas packaging had not proved effective. He stated that methods of deaerating butter oil probably were necessary.

Wilster (47), in 1946, stated that it was probable that butter oil (dry butterfat) would find good use in this country in the future. He reported a process (to be patented) that eliminated the necessity of first churning the cream before making butter oil, as follows: (a) Cream separated at approximately 120° F. by a specially constructed centrifugal separator to a 90-95 percent fat product; (b) oil reseparated to a butter oil containing less than 1 percent moisture; (c) butter oil continuously subjected to high-temperature pasteurization at 195° - 200° F. under partial vacuum, to steam distillation, and to partial cooling in a chamber maintained at nearly complete vacuum in a Vacreator; (d) moisture-free oil congealed continuously in a machine constructed like a continuous ice cream freezer to be extruded and placed in containers. The author emphasized that it was of utmost importance to use cream of the highest quality in the manufacture of butter oil (dry butterfat). He stated that if made from inferior cream, even though the final product might taste perfectly bland, upon emulsification in skim milk, the undesirable flavor became discernible. He further stated that butter oil, if properly packaged, would keep for 1 year without refrigeration at ordinary warehouse temperature, but if it were to be kept for more than a year, 0° F. was a safer temperature.

Hedrick (21), in 1948, reported on methods of manufacture and uses of milk fat (butter oil). He described the preparation of butter oil from butter by the boiling off (not of commercial significance in the United States), filtration, and centrifugation methods; and from cream through destabilization of the fat in water emulsion by freezing, enzymes or acids, agitation, centrifugation, pressure or a combination of one or more of these methods. He pointed out that United States patents cover many aspects of the production of milk fat (butter oil) from cream by breaking the emulsion. He stated that proper deaeration and nitrogen packing would extend the storage life of milk fat (butter oil), and that these processes were recommended, especially if the product were to be stored at temperatures of 60° F. or above. For storage under severe conditions, a moisture of under 1 percent by volume was stated as necessary. Spoilage was reported as due precisely to oxidative changes and occasionally to hydrolytic rancidity (pasteurization at least 170° F. for 2 minutes sufficiently destroyed lipase enzyme to prevent this) and growth of microorganisms (inhibited by moisture content below 0.3 percent) if the milk fat (butter oil) were processed from high-quality sweet cream or from fresh sweet cream butter. The author found that processing temperatures above 190° F. were detrimental to the purified milk fat (butter oil). However, some beneficial effects were noticed by increasing temperatures up to 260° F. if the cream or milk fat (butter oil) were heated prior to removal of the serum. He stated that good-quality milk fat (butter oil) could be used in ice cream and frozen desserts, baking products, confections, soft cheeses or spreads, flavored milk drinks, and as a source of fluid milk or cream by combination with low temperature nonfat powder and water.

Krukovsky (25), in 1948, reported that only pure fat (butter oil) and the fat from butter churned from sweet, fresh cream pasteurized at 170° F. for 30 minutes were not found susceptible to oxidation at the end of 1 and 2 years of storage.

Decker (11, 12), in 1949, reviewed two processes for making butter oil, as follows: (a) Processed from cream --(1) fine-quality cream separated at approximately 120° F. to 90-95 percent fat; (2) oil reseparated to less than 1 percent moisture; (3) oil ran through Vacreator and then congealed continuously by use of Votator. (b) Processed from butter-- (1) butter melted, diluted with warm water, and free fatty acids neutralized; (2) remainder of process same as for cream. He stated that the highest quality cream must be used, as an off-flavor was concentrated and although the dry butterfat (butter oil) might taste bland, upon emulsion with skim milk, the undesirable flavor became apparent. He reported that butter oil keeps well without refrigeration for 1 year at ordinary warehouse temperature, but for storage of more than 1 year a temperature of 0° F. was safer.

In 1950, Dahlberg (10) reported that the Army Quartermaster Corps had found that high-quality dry milk fat (butter oil) and low-heat nonfat dry milk solids could be used for making reconstituted milk having acceptable flavor, appearance, and other required properties. A further report (6) of this product was made in 1951. The butter oil used for reconstitution at overseas bases was shipped frozen in 5-gallon tins.

In 1951, Weinreich (46) stated that good butter oil was made only from good cream. He reported the following process for making butter oil: Separator fed between 4,000 and 5,000 pounds of cream per hour by meter pump. As the cream flowed to the separator, it passed through a destabilizing unit where it was agitated, and then through a continuous heater where it was heated to from 130° to 140° F. The fat was concentrated to about 90 percent in the separator, and was discharged generally as clear, yellow oil with 10-percent skim milk entrained in it. The 90-percent concentrate was diluted to 40 or 50 percent with warm water in a balance tank (neutralized if necessary). From the balance tank, a second separator concentrated the fat to between 99.5 and 99.9 percent, and then the fat was fed, directly into a vacuum pasteurizer, the Vacreator (fat entered first chamber at 140° F. and heated to 200° F. under a 6-inch vacuum; passed to second 175° F. chamber under 16-inch vacuum; passed to third 100° F. chamber under 28-inch vacuum). Fat left the Vacreator at 140° to 145° F. completely dried, deaerated, and pasteurized continuously in a matter of seconds. The fat was then chilled and canned. The minimum time required for the process from raw cream to finished milk fat (butter oil) could be less than 2 minutes.

Smith (40), in 1951, reported the use of butter oil in ice cream. He stated that ice cream manufactured from butter oil was just as good and in some instances superior to ice cream made with fresh sweet cream. He listed the advantages of using butter oil, as follows: High-keeping quality; less bulk than fluid cream; lower freight cost per pound of butterfat; less storage space; lower package cost; lower refrigeration cost; not seasonable or localized product; and ease of handling. He reported that replacement with butter oil of 66 percent of the butterfat derived from fresh sweet cream, would always make the finest ice cream, and would always be acceptable to the trade.

Patton (36), in 1952, experimented with a group of 69 organic liquids to determine their effectiveness in destroying the normal emulsion existing in fresh cream during heating to produce pure milk fat (butter oil). An aqueous reagent containing n-butylamine and n-butanol was developed and found capable of de-emulsifying a number of fluid dairy products.

Stine and Patton (41), in 1952, reported a method of preparing butter oil by de-emulsification of 40 to 45 percent cream with 10 percent or less of 26 different surface-active agents. The procedure was as follows: (1) De-emulsifying agent added with gentle agitation to fresh cream; (2) mixture heated to 180o F. and held at this temperature for 15 minutes after which the lower serum layer was removed by siphoning and replaced with an equal volume of hot water; (3) water-oil mixture thoroughly agitated for about 5 minutes and then passed through a cream separator which had been previously heated with water at 180° F. and adjusted to recover plastic cream; (4) oil from the cream spout was rewashed twice with hot water to remove any de-emulsifying agent or serum solids remaining in it, and then reseparated. The authors stated that it seemed advisable to reserve judgment on the usefulness of the butter oil produced by the above procedure, until the purity and toxicology of the product had been investigated thoroughly.

In 1953, Combs and Morris (9) suggested the marketing of canned butter oil to be used by the housewife in frying or cooking just as butter is used.

Stine and Patton (42), in 1953, reported that by the use of an appropriate surface active agent (Teritol 7, Aerosol OT, or a butylaminebutyl alcohol reagent) to de-emulsify cream, a butter oil could be prepared which was practically identical with butter oil obtained from butter.

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II. Ghee.--Food Product of the Middle East

A product similar to and associated with butter oil has been made for many years in India and Egypt. Such a product is known as ghee by the Hindus (34, 20, 21) 1/, samna or samn by the Egyptians (42, 20, 21) and maslee (20, 21) by the people in other countries in the Middle East. Decker (20) reported that the product is prepared by boiling off water in open kettles and that it is stored for years, "acquiring special flavor and aroma." Of the Middle-eastern products, ghee is the best known to the western world. Reports have been made in journals of India and United States as to method of manufacture, taste, nutritive value, and storage life of ghee. These reports are reviewed in this publication to establish the degree of similarity between ghee and United States butter oil.

HISTORY AND MANUFACTURE

In 1910, Bolton and Revis (12) reported the following method of preparing ghee: Milk (in most cases obtained from buffalo) was boiled, immediately after milking, for 1 to 3 hours in earthen pots. The milk, when cool, was inoculated with sour milk and when the whole milk had become curdled it was churned with a split bamboo stalk. After a half hour's churning, hot water was added, and the churning continued until butter formed. The butter was then skimmed off and kept for a short time. When it became somewhat rancid, it was then heated in an earthen pot, and boiled, until practically all the water present had evaporated. It was then allowed to clarify, and the clear fat was run while warm into jars. This product was reported to be used by the natives for every conceivable culinary purpose, and also to be consumed alone as food. The following vegetable fats were listed as being used in India to adulterate ghee: coconut, groundnut, cottonseed, safflower, poppyseed, sesame and nigerseed. Bolton and Revis (13), in 1911, further reported that of all samples examined, none had led them to believe that pure ghee had anything but a high Reichert-Meissl value, usually approaching or even exceeding 30.

Vakil (43), in 1915, reported analyses of 10 samples of ghee from different ghee-producing districts. His analyses includes the following ranges: Butyro-refractometer at 40° C., 43.5-45.0; saponification value, 218.0-232.2; Reichert-Meissl value, 20.46-25.30; acid value, 1.49-3.63.

1/ Underscored numbers in parentheses refer to literature cited, pp. 20-22.

In 1916, Aiyer (1) reported on methods of butter making in India. He stated that no butter was used as such in Indian households except on rare occasions, but was used in the form of ghee. Ghee was described as butter melted down and boiled to drive off the enclosed water.

Browning and Parthasarathy (14), in 1917, presented data showing that it was possible for pure ghee to have Reichert-Meissl numbers much lower than 30.

In 1920, Ghose (26) reported that at a conference of chemists, it was decided that a sample of ghee would be declared as pure when the Reichert-Wollny value was 30 and above and as adulterated when it was below 28.

Ghare (25), in 1923, stated that ghee was made by heating butter at a gentle heat until it was freed of all water. He recommended that the ghee, while still liquid and warm, be strained through a piece of moist, clean linen and then stored in covered tinned pots or earthenware in a cool place. He reported that market ghee always contained a small amount of water or buttermilk causing some fats to decompose readily and the ghee to turn rancid. Ghee made from fresh butter was reported to keep well for a long time whereas that made from spoiled butter kept for only a very short time.

Kothavala and Cox (31) reported, in 1927, that the separator method (separating whole milk and churning the cream) gave 18 percent more ghee than the desi method (souring and churning whole milk).

Patil and Hammer (35), in 1928, determined that the addition of moisture seemed to hasten the deterioration of ghee more than the addition of protein.

Buchler (15), in 1931, observed that ghee was nothing but melted butter used for most Indian dishes and meals. He stated that when ghee was properly made it could be kept 6 months, and when properly and scientifically packed it could be kept indefinitely.

In 1933, Grewal (29) reported that ghee prepared from centrifuged butter contained a large amount of vitamin A whereas that prepared by the Indian method showed a loss of vitamin A.

Das (16), in 1934, stated that ghee was the most important product of milk in India. He reported the two main problems faced by the ghee trade to be adulteration and defective methods of manufacture. He further reported that by boiling the milk in the evening, cooling it, adding starter, churning to butter in the morning, and boiling the butter to make ghee, a saving in fat loss of 7 percent was obtained.

Datta and Banerjee (18), in 1934, found by means of growth response of young rats that the nutritive value of ghee was the same as that of the original butter.

French and French (24), in 1935, reported that when used in the proportion of 4/5 the normal quantity of butter, ghee made an excellent and very cheap substitute for butter.

Sunawala and Kothavala (41), in 1935, reported the moisture content of ghee to vary from 0 to 0.1 percent; butyro-refractometer readings at 40° C. ranged from 42.8-45.1; Reichert-Meissl values ranged from 20.1 to 28.5 for cow ghee and over 31.0 for buffalo ghee; Polenske values ranged from 0.9 to 2.3; Kirschner value varied between 17.0 and 30.8; saponification values ranged from 218.1 to 231; iodine values varied between 30.4 and 37.9; and acid value showed a maximum of 1.9. They recommended standards for ghee and butter as follows:

Moisture content	Less than 0.7 percent (ghee only).
Butyro-refractometer reading.....	Between 42 and 45.5 at 40°C.
Reichert-Meissl value............	Not less than 20.
Polenske value	Not more than 2.5.
Kirschner value	Not less than 16.
Saponification value	Not less than 2.18.
Iodine value	Between 30 and 38.
Free fatty acids	Less than 1 percent.

Banerjee and Sunawala (9, 10), in 1935 and 1936, emphasized the importance of making vitamin A assays on ghee as it was the principal source of vitamin A for Indians.

Dastur and Banerjee (17), in 1936, listed heat, light, acidity, moisture, enzymes, and metals as factors that might produce rancidity in ghee. They stated that heating at 100° C. had more effect on production of rancidity than exposure to air. The best temperature for preservation of ghee was found to be 0° C. or lower. They reported that some workers had shown that each increase of 10° C. doubled the rate of increase of rancidity. Rancid products could be materially improved by removing the products of decomposition but fat so purified would again become rancid rapidly according to the authors. They stated that ghee prepared under good conditions could be preserved with care for about 6 months, but that bazaar ghee was seldom stable for more than a fortnight.

Banerjee (3), in 1936, reported that vitamin A was stable in ghee for only a month. During storage, it slowly went down and was reduced to half in 6 months and was transformed or oxidized in about a year. Loss of aroma and the development of a tallowy odor, followed the destruction of the vitamin A in ghee. The author (5), in 1936, found that destruction of vitamin A and the penetration of light was directly proportional to the light intensity. Destruction of vitamin A due to direct sunlight, especially in thin layers of ghee, was found to be "alarming." It was concluded that ghee should be kept in the dark or in very weak light and exposure to sunlight should be avoided.

In 1937, Banerjee and Dastur (6) reported that vitamin A in ghee was fairly stable at temperatures up to 125° C., but was rapidly destroyed at higher temperatures. Aeration of hot ghee samples lowered the stability of the vitamin. The rate of destruction was found to be independent of the temperature and volume of air used. Cow ghee was found to be superior to buffalo ghee with respect to the stability of its vitamin A toward heat. The authors (7) reported further, in 1937, that the stability of vitamin A in ghee depended to a great extent on the other natural coloring materials accompanying it, particularly carotene.

Wright (44), in 1937, stated that ghee was judged by its appearance and texture, taste, and aroma. The product should be light yellow, have a fine granular texture, be neither greasy nor waxy, taste slightly acid, and have no taint or abnormal flavors. He reported the acidity on 4,380 samples of ghee. The acidity on 86.3 percent of the samples was more than twice as high as the range given for butter.

Ritter (39), in 1937, stated that ghee was obtained by melting butter at a temperature of about 40° to 50° C. and separting the fat from the aqueous part, or by removing the moisture by steam evaporation. He reported that cooked butter (ghee) was more liable to oxidation than the original butter because of the loss of elements which protect the fat against oxidation in the residue. He concluded that the keeping quality of well-cooked butter was better than that of butterfat melted at a low temperature.

Banerjee (4), in 1938, reported that hydroquinone, sodium salts of tartaric and citric acid, and carotene obtained from three sources acted as anti-oxidants in ghee. Nitrogen gas was found to retard autoxidation. Acidity in ghee, whatever the cause of development, was reported to be highly pro-oxidant and to destroy vitamin A rapidly under heat.

In 1938, Banerjee and Doctor (8) stated that although acidity is undesirable in butter and ghee, good quality butter or ghee of rich aroma can only be prepared after proper souring of the milk or cream. An acidity of 0.44 percent in the sour cream was found to be the best figure for practical purposes. Butter or ghee from fresh milk was reported to be of good keeping quality, but was without flavor.

In a 1939 report, (37) it was indicated that a suspicion of adulteration was justified in ghee with a Reichert-Meissl value below 25.

Khubchandani (30), in 1939, reported the keeping quality of ghee to be improved by adding citric acid and sodium citrate to the cream used.

Govindarajan and Banerjee (27, 28), in 1939 and 1940, reported the use of an alcohol-soluble, vegetable dye, Kamala, as an antioxidant for ghee. The induction period was found to be considerably increased by the addition of as little as 0.02 percent of the dye. Organic acids, such as citric, tartaric, and lactic acid did not increase the period of induction, whereas oleic acid was found to shorten it. When the acids were added with antioxidants, however, a considerable increase in the antioxidative

activity was noted. This effect was particularly noticeable with oleic acid. Antioxidants in inhibiting fat oxidation were found also to delay the destruction of vitamin A in ghee.

Doctor, et al. (23), in 1940, reported the range of variation for the various constants for ghee, as follows:

	Cow ghee	Buffalo ghee
Reichert value	Not less than 23	Not less than 30
Polenske value	1.5 to 3.0	1.5 to 3.0
Kirschner value	Not less than 19	Not less than 25
Iodine value	26 to 38	30 to 38
B.R. reading at 40°C.	40 to 46	40 to 46

They found that the methods of preparation of ghee had no appreciable effect on the Reichert value and other constants of ghee. Different breeds of cattle and even individuals of the same breed differ in their ability to transfer carotene from their food into their butterfat. The composition of milk fat of animals fed on oil cakes tended to become similar to that of the oil. The feeding of oil cakes had a marked effect on the body and texture of ghee. Some oil cake feeds increased the iodine value and decreased the Reichert-Meissl value whereas coconut cake had no effect on the Reichert value.

Davies (19) stated, in 1940, that it was estimated that ghee accounted for 53 percent of the total milk produced in India or for 77 percent of the milk used for the manufacture of milk products. He reported a difference of opinion as to the ideal flavor for ghee, but common agreement that ghee must have some strength of flavor--not be bland like pure butterfat. The main components of ghee flavor were given as: Butter flavor (diacetyl); acid flavor (butyric and other volatile acids, oleic acid); and flavors introduced in the heating process such as faint burnt flavor and burnt casein flavor. The author stated that the only rancidity to which ghee was susceptible was oxidative rancidity, and recommended that the acid value be kept as low as possible, and that unnecessary contamination with heavy metals and unnecessary exposure to sunlight be avoided. The following standards for ghee were listed as being prescribed by some provincial governments:

Type	Max. moisture content	Butyro-refractometer reading	Saponification value	Reichert-Meissl value
	Percent		Not less than	
Cow, buffalo, and mixed	1.0	40.0 to 42.5	220	24 28 (buffalo and mixed)
Agmark (all types)	0.5	40.0-42.5	222-226	26 (cow) 30 (buffalo) 28 (mixed)

In 1941, Narasimhamurty (33) stored ghee at 20° to 30° C. in dark brown and colorless bottles in diffused light for 7 months. The samples were analyzed before and after storage for Reichert-Meissl, Polenske, and iodine values. The Reichert-Meissl values, except in few instances, decreased; the Polenske values, with one exception, increased; and the iodine values were irregular. The author could not confirm reported observations that with the development of acidity the iodine and Polenske values decreased and the Reichert-Meissl values increased.

Majumdar (32), in 1941, reported that cow's butter with 16.6 percent moisture, 17.7 I.U. of vitamin A per gram, and 8.4 I.U. of carotene produced ghee with no moisture, 14.7 I.U. of vitamin A and 6.8 I.U. of carotene.

Purchase (38), in 1943, produced ghee from camel's milk. The product was almost white in color, appeared waxy in texture, had no butyric odor, but smelled faintly of mutton fat and had a "camel" or tallowy flavor. The melting point was 43.5 to 44.7° C. and the solidifying point was 34 to 35° C. It had a low Reichert-Meissl value.

Barnicoat (11), in 1945, described ghee as dried butterfat prepared from the milk of the buffalo or the cow differing from New Zealand cow butterfat in being yellowish white in color, harder, and of a pungent, almost rancid flavor. He stated that dried butterfat prepared from New Zealand butter by direct methods (boiling, centrifuging, and vacuum evaporation) and submitted to authorities in India proved moderately acceptable despite its yellow color, softer texture, and absence of real "ghee flavor."

Persai and Barnicoat (36), in 1949, stated that problems relating to the keeping quality of ghee had not been investigated to any extent, and that results given in the literature were rather confusing. Of the four main factors (moisture content, acidity, heat treatment, and type of bacterial culture used in souring) commonly regarded as influencing the keeping properties of ghee, the heat treatment was found to be the most important. In general, the higher the final temperature, (110° C. or higher) attained during evaporation, the better were the keeping properties of the product, provided the butter had been heated in contact with curd, boiled as rapidly as possible, and given a minimum amount of stirring. The authors concluded that the improved keeping properties conferred on ghee heated to 110°-150° C. were promoted by antioxidants (apparent phospholipids) extracted from the curd during cooking.

Bahadur, et al. (2) in 1950, clarified butter to form ghee by heating the butter to form 3 layers, the middle layer being liquid fat. By removing the bottom layer and heating the 2 top layers, the ghee contained less moisture and acid, more vitamin A, and a better aroma than ghee made by the conventional open kettle method .

In 1951, Dhar (22) reported that green chilies, garlic, and onion were used in India as antioxidants in ghee. The author dialyzed these antioxidants in alcohol. The portion of the dried dialysate that dissolved in petroleum ether exhibited high antioxidant properties.

Sirajuddin (40), in 1951, reported storage data for different types of Pakmak (Pakistan) ghee packed and sealed in ordinary tin containers and kept in merchant's "godowns" at room temperature, as follows:

Grade	Type of milk ghee (when produced)	Storage period months
Special	Winter-Oct.-Dec.	5 to 6
	Winter-Jan.-Mar.	3 to 5
Special	Summer-Apr.-June	3
	Summer-July-Sept.	3 to 6
General	Winter-Oct.-Dec.	4 to 5
	Winter-Jan.-Mar.	3 to 4
General	Summer-Apr.-June	2
	Summer-July-Sept.	2 to 5
Regional	Winter-Oct.-Dec.	3 to 4
	Winter-Jan.-Mar.	2 to 3
Regional	Summer-Apr.-June	2
	Summer-July-Sept.	2 to 3

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